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Abstract

Examination of an In-Pile-Burnout Damage on a Boiling Water Fuel Rod

by

R. Schwarzwälder, J. Höchel, J. Fischer
Allgemeine Elektricitäts-Gesellschaft

Within an extensive irradiation program for development of boiling water fuel elements, burnout damages occurred on three fuel rods due to insufficient cooling. Since there is still a very limited knowledge of in-pile-burnout damages, the opportunity offered by this unforeseen circumstance, was taken to determine by metallographical and other methods of analysis the state of one of these rods after having been damaged.

The irradiation tests have been performed under boiling water reactor conditions, i.e. 70 at, subcooled boiling, in a pressure-tight capsule in the so-called Trail Cable Facility in the GETR in Vallecitos.

The characteristics of the fuel rod selected for the analysis prior to being inserted into the reactor are as follows:

Cladding material	stainless steel
Outside diameter of the cladding	13.82 mm
Wall thickness of cladding	0.51 mm
Fuel	UO_2 pellets, 4.5 % enriched
Average fuel diameter	12.4 mm
Radial gap	0.2 mm
Filling gas in the gap	Xenon
Length of fuel column	170 mm
Total length of specimen	200 mm

The average thermal flux at the respective position in the GETR was approximately 7.5×10^{13} nv. Enrichment and diameter of the specimens

have been selected in such way that at maximum an average heat flux of approximately 170 W/cm^2 could be expected.

The burnout was probably caused by hydraulic instability of the cooling water under natural circulation. It occurred immediately after being inserted into the reactor when the specimen was moved towards regions of higher flux.

The specimen removed from the capsule in the hot laboratory of VAL showed that an extensive, but not complete melting of the cladding has occurred in the upper 60 % of the rod. The flow of melted steel could distinctly be noticed in the center of the specimen. At some points the cladding had completely disappeared and exposed the underlying UO_2. Approximately in the center the specimen was nearly broken and at further handling it fell into two pieces.

The metallographical analysis showed that melted steel of the cladding has flown towards the fuel axis at the pellet interfaces and into radial cracks. The penetration was rather considerable as could be proven by identifying relatively large quantities of stainless steel in small and smallest cracks of the fuel.

A considerable oxidation of the external cladding surface has been detected and by means of an X-ray analysis the main reaction products have been determined.

The analysis of the microstructure of UO_2 showed an extensive columnar growth of grain. Melting could be observed in the center.

Summarized the examination shows:

1. that apparently there was no reaction between UO_2 and stainless steel although the melted stainless steel was dispersed rather extensively in tne fuel and
2. that there was no vigorous reaction between the stainless steel and the coolant although a strong oxidation of the melted cladding could be observed.